FA Composition of Crude Oil Recovered from Catfish Viscera

Subramaniam Sathivel[a,1], Witoon Prinyawiwatkul[a,*], Casey C. Grimm[b], Joan M. King[a], and Steven Lloyd[b]

[a]Department of Food Science, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803-4200, and [b]USDA, ARS, SRRC, New Orleans, Louisiana 70124

ABSTRACT: The FA composition of crude catfish oil recovered from whole viscera, digestive tract, liver, gallbladder, and visceral storage fat was determined and compared with that of fillet and nugget (abdominal portion). About 34% crude fat (wet basis) could be recovered from the whole catfish viscera. FA found in crude catfish visceral oil were C14:0, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3, C20:0, C20:1, C20:2, C20:3, C20:4, and C22:6, the predominant FA being C18:1, C16:0, C18:2, and C18:0. Catfish visceral oil was characterized by a high level of unsaturated FA, which was similarly found in fillet and nugget. Total unsaturated FA in visceral oil amounted to 261.3 mg/g (dry basis) compared to that of fillet (259.3 mg/g) and nugget (307.6 mg/g). The whole viscera contained 4.2 mg/g DHA compared to that of gallbladder (9.2 mg/g), fillet (9.3 mg/g), and nugget (10.7 mg/g). The total n-3 FA in the whole and/or portioned viscera ranged from 4.3 to 20.9 mg/g.

Paper no. J10212 in *JAOCS 79,* 989–992 (October 2002).

KEY WORDS: Catfish, FA composition, oil, processing waste, viscera.

The channel catfish (*Ictalurus punctatus*) production and processing industries in the United States have been growing drastically to accommodate rapid changes in supply and consumer demand for fish and seafood. Catfish is now the fourth most popular fish product consumed in the United States (1). The total water surface acreage for catfish production has increased from about 56,000 acres (22,662 hectares) in 1980 to more than 185,700 acres (75,151 hectares) in 2001 (1). Catfish processed in 1980 in the United States was about 46.5 million pounds (21.09 million kilos) (live weight), and by 2000 this number had increased to about 594 million pounds (269.44 million kilos) (2). Most catfish processed in the United States is sold as fresh or frozen fillets and whole-dressed fish. Yield from a dressed catfish from traditional processing is only 45%, whereas offal (including frames, viscera, skin, and trimmings) derived from the filleting process (which often ends up in landfills or rendering plants) amounts to 55% of the total weight of live catfish.

To the best of our knowledge, no attempt has been made to add value to catfish viscera, a processing waste. The whole viscera (WV), which includes liver (L), gallbladder (GB), digestive tract (DT, i.e., intestine and stomach) and visceral storage fat (VSF), weighs about 10% by weight of a live whole catfish. Multimillion pounds of catfish oil from processing waste that could be recovered and converted into edible oil are now being wasted instead.

n-3 FA play a major role in human health (3). Natural fish oils have been claimed to help maintain heart and vascular health in humans (4). Some beneficial effects of n-3 FA on certain diseases, functions, and malfunctions have been found, including heart disease (5), cardiovascular functions (6), and possible influences on brain growth during early infancy (7).

Catfish oil recovered from processing wastes may provide a good source of health-promoting FA. This study was conducted to characterize the FA profile of crude oil recovered from catfish viscera and various parts of viscera, i.e., L, DT, GB, and VSF, and to compare the profile with that of fillet (F) and nugget (N, abdominal portion).

EXPERIMENTAL PROCEDURES

Sample preparation. Fresh catfish WV, F, and N were obtained in three separate batches from a local seafood store in Baton Rouge, Louisiana. The WV was separated into GB, L, DT, and VSF. Each sample part (WV, GB, L, DT, VSF, F, and N) was individually weighed, ground with a commercial blender for 10 min, and stored at −20°C until analyzed.

Fat, protein, and moisture analysis. The fat content of each sample was analyzed according to AOAC procedure 985.14 (8). An automated solvent extractor equipped with a microwave moisture analyzer (CEM Corp., Matthews, NC) was used for the moisture and fat analyses. Approximately 4 g of ground sample was used. Methylene chloride was used as a solvent for fat extraction. Percent protein (Kjeldahl N × 6.25) was determined by AOAC procedure 992.15 (8). An average of nine values (three batches; three replications for each batch) for fat, protein, and moisture content was reported.

Fat extraction. Fat extraction was done for each of the seven individual samples (WV, GB, L, DT, VSF, F, and N). About 5 g of each ground sample was placed in a screw-capped test tube, then 5 mL of distilled water, 20 mL of chloroform, and 20 mL of methanol (1:4:4 by vol) were added to the tube, and the mixture was homogenized on a vortex for 10 min. The homogenized mixture was filtered through Whatman No.1 filter paper. The filtrate was then placed into a separatory funnel, and the bottom layer of the solution was collected. Anhydrous sodium sulfate (5.7 g) was added to the collected aqueous solution to remove water. Residual solvent

[1]Current address: Fishery Industrial Technology Center, University of Alaska Fairbanks, 118 Trident Way, Kodiak, AK 99615.
E-mail: sathivel@sfos.uaf.edu

*To whom correspondence should be addressed. E-mail: wprinya@lsu.edu

was removed from the solution by the Meyer-N-Evaporator (an analytical evaporator) (Organomation Associates Inc., West Berlin, MA) under nitrogen atmosphere. The evaporation was continued until the solution was free of chloroform. The extracted sample was kept at –20°C until used. Fat extraction was repeated nine times (three batches; three extractions for each batch) for the seven individual samples.

Esterification of FA. FAME were prepared following AOAC procedure 969.33 (8). Each extracted catfish oil was placed separately into a 50-mL flat-bottomed boiling flask containing approximately 4 mL of methanolic sodium hydroxide (2 g of NaOH dissolved in 100 mL of methanol), and 10 boiling chips were added to the flask. The condenser and reflux units were attached to the flask and refluxing took place, with immediate addition of 7 mL of boron trifluoride through the condenser, for 12 min. The esterified FA were extracted from the mixture by adding 5 mL of heptane and refluxing for 1 min. The esterified solution was allowed to cool to room temperature. A saturated solution of sodium chloride was added and the flask was gently rotated. A saturated sodium chloride solution was added until the heptane solution containing FAME reached the neck of the flask. The heptane solution containing FAME was then recovered, dehydrated with 1.5 g anhydrous sodium sulfate, and stored under nitrogen in Teflon-capped vials at –20°C until analyzed.

FA analysis. The FAME were quantified with a Hewlett-Packard 5890 Series II gas chromatograph equipped with a Hewlett-Packard 7673A autosampler (Palo Alto, CA) and interfaced with a 5970 mass selective detector (Agilent Technologies, Palo Alto, CA). The GC was equipped with an EZ-Flash fast-temperature programmable column (Thermedics Detection, Inc., Chelmsford, MA). The column phase was RTX-2330 (90% biscyanopropyl/10% phenylcyanopropyl polysiloxane) with the following dimensions: 5 m long, 0.25 mm i.d. with a 0.2 μm phase thickness. One microliter was injected using the inlet in a split mode. The head pressure was set at 2 psi, and the split vent flow was 7 mL/m. The injector temperature was 260°C. The column flow rate at 2 psi was 0.68 mL/m. The column temperature was ramped from 50 to 260°C at 20°C/s and was held at 260°C for 90 s. The total run time was 5 min. The transfer line temperature was 280°C. The mass selection detector was operated in the selected ion monitoring mode. FA were identified by retention times obtained from the FAME standards (Sigma Company, St. Louis, MO). Three experimental replications (batches) were conducted, each with three extractions and three GC injections per extraction. The FA content was reported as mg/g dry-sample weight.

Statistical analysis. All data were analyzed using an SAS program (9). An ANOVA was performed to determine differences in FA profiles of samples. Tukey's Studentized range test was performed for *post-hoc* multiple comparisons. Group differences, expressed in terms of differences in mean vectors of the FA, were determined using a multivariate analysis of variance (MANOVA). Principal component analysis was used to group the samples with similar FA. Descriptive discriminant analysis (DDA) (10) was performed to identify the FA underlying the group differences among FA profiles of WV and the various parts of viscera. Based on DDA, the first two orthogonal canonical correlation matrices (dimensions) were used, which cumulatively explained 97% of the variance.

RESULTS AND DISCUSSION

Proximate composition. WV of catfish, which includes L, DT (intestine and stomach), GB, and VSF, weighs about 265 g, which is approximately 14% by weight of a live catfish. The average weight of catfish L, GB, DT, and VSF in this study was 65, 8, 90, and 80 g, respectively. Weight of catfish L was relatively higher than that of other marine fish (e.g., notothenioid fish from Admiralty Bay) reported by Kamler *et al.* (11). The F and N made up an average of 45–55% of the whole catfish weight. Fat, protein, and moisture contents of the various parts of the catfish are shown in Table 1. The carbohydrate and fiber contents of the WV and portioned visceral parts (except those of GB) were lower than 5% (wet basis). Fat content (% wet basis) of WV, L, DT, GB, VSF, F, and N was 33.6, 8.8, 5.8, 0.3, 90.7, 9, and 14.7%, respectively. Catfish store fat in the visceral cavity as VSF. The fat content of catfish viscera from our study was higher than that reported by Belal and Assem (12).

The average protein content of F and N (Table 1) agreed with values from other studies (12,13). The average moisture content of N and F was similar to that reported by Belal and Assem (12). However, the moisture content was slightly higher than that reported by Brooks (14). An inverse relationship existed between the total lipid content and moisture content, and this relationship is common to all species of fish (12,14).

FA profile. The FA compositions of WV, DT, L, GB, VSF, F, and N are shown in Table 2. The major FA present in catfish viscera were palmitic (C16:0), stearic (C18:0), oleic (C18:1), and linoleic (C18:2). Principal component analysis (data not shown) indicated a clear distinction among FA profiles of WV and those from portioned visceral parts. DDA (data not shown) identified C14:0, C18:3, and C20:0 (the first dimension, with 93% variance explained) and C20:4 and C22:6 (the second dimension, with 97% cumulative variance explained) as the discriminating FA in catfish oils. The oil from catfish viscera was characterized by a high level of

TABLE 1
Fat, Protein, and Moisture Content[a] of Catfish Viscera, Visceral Parts, Fillet, and Nugget

Catfish parts	Fat[b] (%)	Protein[b] (%)	Moisture (%)
Whole viscera	33.6	14.7	50.1
Digestive tract	5.8	13.4	79.5
Liver	8.8	11.4	74.9
Gallbladder	0.3	2.6	88.9
Visceral storage fat	90.7	1.3	8
Fillet	9	14.4	74.4
Nugget	14.7	13.5	71.2

[a]An average of nine values.
[b]Wet weight basis.

TABLE 2
FA Profiles of Catfish Viscera, Fillet, and Nuggets (mg/g dry basis)[a]

FA	Whole viscera	Digestive tract	Liver	Gallbladder	Storage fat	Fillet	Nugget
C14:0	9.5	1.4	0.3	0.3	5.2	6.8	10.4
C16:0	76.2	43.2	7.2	5.3	33.9	70.4	83.6
C16:1	10.9	3.7	1.1	1.3	5.1	14.0	10.8
C18:0	32.9	10.9	6.7	13.9	13.1	29.7	35.6
C18:1	145.7	62.0	12.2	3.1	52.7	149.5	175.7
C18:2	73.1	1.5	2.8	0.4	29.5	65.6	81.2
C18:3	7.5	17.3	0.3	0.2	4.3	6.0	8.3
C20:0	1.9	0.6	0.2	0.5	0.9	1.5	1.9
C20:1	11.9	1.9	1.0	0.9	4.6	7.9	10.9
C20:2	3.5	1.3	0.2	2.1	2.2	2.3	3.6
C20:4	4.5	3.0	6.4	2.8	1.9	4.7	6.4
C22:6	4.2	3.6	4.0	9.2	1.8	9.3	10.7
Saturated	121.0	56.2	14.4	25.0	53.0	108.4	131.5
Unsaturated	261.3	94.7	28.0	79.4	102.1	259.3	307.6

[a]Mean values of 27 measurements (three batches, each with three extractions and three injections per extraction). SD of each FA is less than 5%.

TABLE 3
Comparison of FA Profiles of Whole Catfish Viscera with Some Fish Fillets

FA (g/100 g of raw tissue)	Wild catfish[a]	Farmed catfish[a]	Farmed salmon[a]	Bluefin tuna[a]	Whole viscera[b]
Saturated					
C14:0	0.06	0.09	0.49	0.14	0.42
C16:0	0.44	1.23	1.30	0.81	3.35
C18:0	1.50	0.35	0.28	0.31	1.44
Monounsaturated	0.84	5.59	3.87	1.60	7.40
C16:1	0.18	0.28	0.67	0.16	0.48
C18:1	0.59	3.17	1.78	0.92	6.40
C20:1	0.02	0.07	1.19	0.28	0.55
Polyunsaturated	0.87	1.57	3.93	1.43	4.10
C18:2	0.10	0.88	0.59	0.05	3.21
C18:3	0.07	0.10	0.09	0.00	0.33
C20:4	0.15	0.09	1.15	0.04	0.20
C22:6	0.23	0.21	1.29	0.89	0.18
n-3	0.30	0.31	1.38	0.89	0.51

[a]Reference 21.
[b]From our study.

unsaturated FA. Oleic acid was dominant among unsaturated FA, whereas palmitic acid was dominant among saturated FA. The amount of unsaturated FA in WV was significantly (α = 0.05) higher than those in portioned visceral parts, and was almost equal to that of F but lower than that of N. Among all FA, oleic acid (C18:1n-9) was present in the largest quantity in WV as well as in DT, L, and VSF. The GB contained 9.2 mg/g (dry basis) of DHA, whereas F had the highest amount of DHA (10.7 mg/g). The largest amounts of myristic acid (9.5 mg/g) and stearic acid (32.9 mg/g) were found in whole viscera when compared to L, GB, DT, and VSF.

Unsaturated FA accounted for 307.6, 261.3, 259.3, 102.1, 94.7, 79.4, and 28 mg/g for N, WV, F, VSF, DT, GB, and L, respectively. A significant difference was found in the level of unsaturated FA and in n-3 and n-6 FA among whole and portioned viscera. The total n-3 FA (combined C18:3n-3 and C22:6n-3) in WV, DT, L, GB, VSF were 11.7, 20.9, 4.3, 9.4, and 6.1 mg/g, respectively, whereas the total n-3 FA were 15.3 and 18.6 mg/g for F and N, respectively. The n-3/n-6 ratio of catfish oil from viscera is low, which is typical for lipids of cultured fish (15). The n-3/n-6 ratio of cultured fish ranges from 0.5 to 3.8 (15). The FA of fish are derived from two main sources, namely, biosynthesis and diet (11,16–18). Catfish WV, F, and N were characterized as having higher quantities of C18:2n-6.

The predominance of C18:2n-6 in catfish has been attributed to the fishmeal diet, especially if it is made from soy products. Diet has a major effect on the FA composition of L lipids, especially n-3 FA (19). Fish can accumulate n-3 FA in L lipids when the diet contains either linolenic acid (18:3n-3) or DHA (22:6n-3) (19). The mean level of 18:3n-3 was 0.3 mg/g of tissue in L. Although it was low, it was similar to that of other fish such as the Japanese surgeonfish (*Naso lituratus* and *Acanthurus lineatus*) (20).

In Table 3, selected FA in WV are compared with values from USDA FA data for selected fish (21). PUFA of catfish WV (4.10 g) were similar to those of the muscle of farm-raised salmon (3.93 g) but higher than those of bluefin tuna (1.43 g) and farmed catfish (1.57 g). Total n-3 FA (C18:3 and C22:6) in WV accounted for 12.4% of the PUFA, whereas they accounted for 35 and 62% in tuna and salmon muscle, respectively.

Multimillion pounds of oil from catfish viscera, a processing waste, could be recovered and converted into edible oil. However, a purification process is necessary to remove the lipophilic contaminants, including heavy metals and pesticides, that may be found at elevated levels in the fat of farm-raised catfish.

ACKNOWLEDGMENT

The Louisiana Agricultural Experiment Station Manuscript Number 02-21-0121.

REFERENCES

1. NASS-USDA, Catfish Products, National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture, Washington, DC, 2001.
2. NASS-USDA, Catfish Processing, National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture, Washington, DC, 2001.
3. Kronhout, D., E.B. Bosschieter, and C. Coulander, The Inverse Relation Between Fish Consumption and 20-Year Mortality from Coronary Heart Disease, *N. Engl. J. Med. 312*:1205–1209 (1985).
4. Haglund, O., R. Wallin, S. Wretling, B. Hultberg, and T. Saldeen, Effects of Fish Oil Alone and Combined with Long Chain (n-6) Fatty Acids on Some Coronary Risk Factors in Male Subjects, *J. Nutr. Biochem. 9*:629–635 (1998).
5. O'Keefe, J.H. and W.S. Harris, Omega-3 Fatty Acids: Time for Clinical Implementation? *Am. J. Cardiol. 85*:1239–1241 (2000).
6. Simopoulos, A.P., Omega-3 Fatty Acids in the Prevention Management of Cardiovascular Disease, *Can. J. Physiol. Pharmacol. 75*:234–239 (1997).
7. Xiang, M., G. Alfven, M. Blennow, M. Trygg, and R. Zetterstrom, Long-Chain Polyunsaturated Fatty Acids in Human Milk

and Brain Growth During Early Infancy, *Acta Paediatr. 89*: 142–147 (2000).
8. AOAC, *Official Methods of Analysis of the Association of Official Analytical Chemists,* 14th edn., Arlington, VA, 1990.
9. Statistical Analysis System, *SAS User's Guide: Statistics,* SAS Institute, Cary, NC, 2001.
10. Huberty, C.J., *Applied Discriminant Analysis,* John Wiley & Sons, New York, 1994.
11. Kamler, E., B. Krasicka, and S. Rakusa-Suszczewski, Comparison of Lipid Content and Fatty Acid Composition in Muscle and Liver of Two Notothenioid Fishes from Admiralty Bay (Antarctica): An Eco-physiological Perspective, *Polar Biol. 24*: 735–743 (2001).
12. Belal, I.E.H., and H. Assem, Substitution of Soybean Meal and Oil for Fish Meal in Practical Diets Fed to Channel Catfish *Ictalurus punctatus* (Rafinesque): Effects on Body Composition, *Aquacult. Res. 26*:141–145 (1995).
13. Liebowitz, H.E., Replacement of Fish Meal with Soybean Meal in Practical Catfish Diet, Master's Thesis, Auburn University, Auburn, AL, 1981.
14. Brooks, G.M., Rancidity Problem in Frozen Stored Catfish, in *Fourth Annual Proceedings Catfish Farmers of America Research Workshop*, Food and Fiber Center, Mississippi Cooperative Extension Service, Mississippi State University, Mississippi State, 1982, pp. 1–3.
15. Love, R.M., *The Chemical Biology of Fishes,* Academic Press, London, 1970.
16. Hearn, T.L., S.A. Sgoutas, J.A. Hearn, and D.S. Sgoutas, Polyunsaturated Fatty Acids and Fat in Fish Flesh for Selecting Species for Health Benefits, *J. Food Sci. 52*:1209–1211 (1987).
17. Chanmugam, P., M. Boudreau, and D.H. Hawang, Differences in the ω-3 Fatty Acid Contents in Pond-Reared and Wild Fish and Shellfish, *J. Food Sci. 51*:1556–1557 (1986).
18. Morris, C.A., K.C. Haynes, J.T. Keeton, and D.M. Gatlin, Fish Oil Dietary Effects on Fatty Acid Composition and Flavor of Channel Catfish, *J. Food Sci. 60*:1225–1227 (1995).
19. Satoh, S., W.E. Poe, and R.P. Wilson, Effect of Dietary n-3 Fatty Acids on Weight Gain and Liver Polar Fatty Acid Composition of Fingerling Channel Catfish, *J. Nutr. 119*:23 (1989).
20. Montogomery, W.L., T. Umino, H. Nakagawa, I. Vaughn, T. Hibuno, Lipid Storage and Composition in Tropical Surgeonfishes (Teleostei: Acanthuridae), *Mar. Biol. 133*:137–144 (1999).
21. U.S. Department of Agriculture, Agricultural Research Service, USDA Nutrient Database for Standard Reference, Release 14, Nutrient Data Laboratory Home Page, http://www.nal.usda.gov/fnic/foodcomp (accessed July 2001).

[Received January 11, 2002; accepted June 11, 2002]